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ELECTRON SWARM HAVING AN ANISOTROPIC VELOCITY DISTRIBUTION FUNCTION

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INTRODUCTION

In recent years there has been a renewed interest in the velocity distribution function of electrons in weakly ionized gases. In this report we present the theoretical analysis of the electron swarm in a relatively high $E/N$, considering an anisotropy of the distribution function. The present developed theory is applied to the electron swarms in neon.

BASIC THEORY

The Boltzmann equation for the velocity distribution function $g(r,v,t)$ of electrons moving through a slightly ionized gas under the influence of a uniform electric field $E$ is

$$\frac{3g}{3t} + v \frac{3g}{3v} + \frac{eE}{m} \frac{3g}{3v} = J(g) \tag{1}$$

where $v$ is the electron velocity, $e$ the elementary charge, $m$ the electron mass, and $J(g)$ the collision integral.

We express the distribution function in the form of the first three-terms of the spherical harmonic expansion in order to make clear the anisotropy of the function $g(r,v,t) = \tilde{g}_0(r,v,t) + \tilde{g}_1(r,v,t) \cos \theta + \tilde{g}_2(r,v,t) \sin \theta \tag{2}$

where $\tilde{g}_0$ is the isotropic part of the distribution function, $\tilde{g}_1$ and $\tilde{g}_2$ the first and second anisotropic parts, and $\theta$ the angle between $v$ and $E$. When the expansion (2) is inserted into the equation (1) under the condition of one dimensional spatial gradient along the field direction ($z$ axis), we find the integrodifferential equation for $\tilde{g}_0$, $\tilde{g}_1$, and $\tilde{g}_2$.

In equation (3), the first square bracket represents a divergence in velocity space, and the second square bracket shows a divergence in position space. The rest of the right side show the terms of the inelastic collisions including ionization.

Here, we may estimate $\tilde{g}_2$ as

$$\tilde{g}_2(r,v) = -\left(\frac{2}{3}\right)^2 \frac{1}{2} \frac{3}{4N_0} \left[ \frac{3^2}{32} + \frac{3}{4N_0} \frac{3}{4N_0} \frac{3}{4N_0} \right] \tag{4}$$

In these circumstances, the electron swarm is subject to a continuity equation of the form

$$\frac{3g}{3t} = -\frac{3}{2} \left( H(s,t)n(s,t) + D_L(s,t) \right) \tag{5}$$

where

$$D_L = D_0 - \frac{9}{135} \frac{eE}{m} \frac{3}{4N_0} \left[ \frac{3}{4N_0} \frac{3}{4N_0} \frac{3}{4N_0} \right] \tag{6}$$

$$D_0 = \left( \frac{1}{3} \right)^2 \frac{4}{3} \frac{3}{4N_0} \tag{7}$$
RESULTS and DISCUSSION

The electron energy distribution functions in neon are computed from the present theory in a range of $E/N$ from 141.3 to 1130 Td for a steady state condition. Figure 1 and 2 show each term of the energy distribution functions $f_k(\varepsilon) = \frac{4\pi}{m^2} \rho_k(\nu)$ as a parameter of $E/N$. Also shown in these figures are the results of the usual two term Lorentz approximation for comparison. The validity of the Lorentz approximation will be judged from the direct comparison between them.

The swarm coefficients derived from the present distribution functions, especially, longitudinal and transverse diffusion coefficients are exhibited in figure 3. It is found that the gradual increase of the anisotropy with the increase of $E/N$.

![Figure 1](image1.png)  
**Figure 1.** Theoretical isotropic and anisotropic parts of the distribution function for $E/N$ of 282.5 Td in neon  
---: three term approximation  
---: Lorentz approximation

![Figure 2](image2.png)  
**Figure 2.** Theoretical isotropic and anisotropic parts of the distribution function for $E/N$ of 706.3 Td in neon  
---: three term approximation  
---: Lorentz approximation

![Figure 3](image3.png)  
**Figure 3.** Longitudinal and Transverse diffusion coefficients in neon derived from the present distribution functions.